R&D Issues in the Office of Energy Efficiency and Renewable Energy

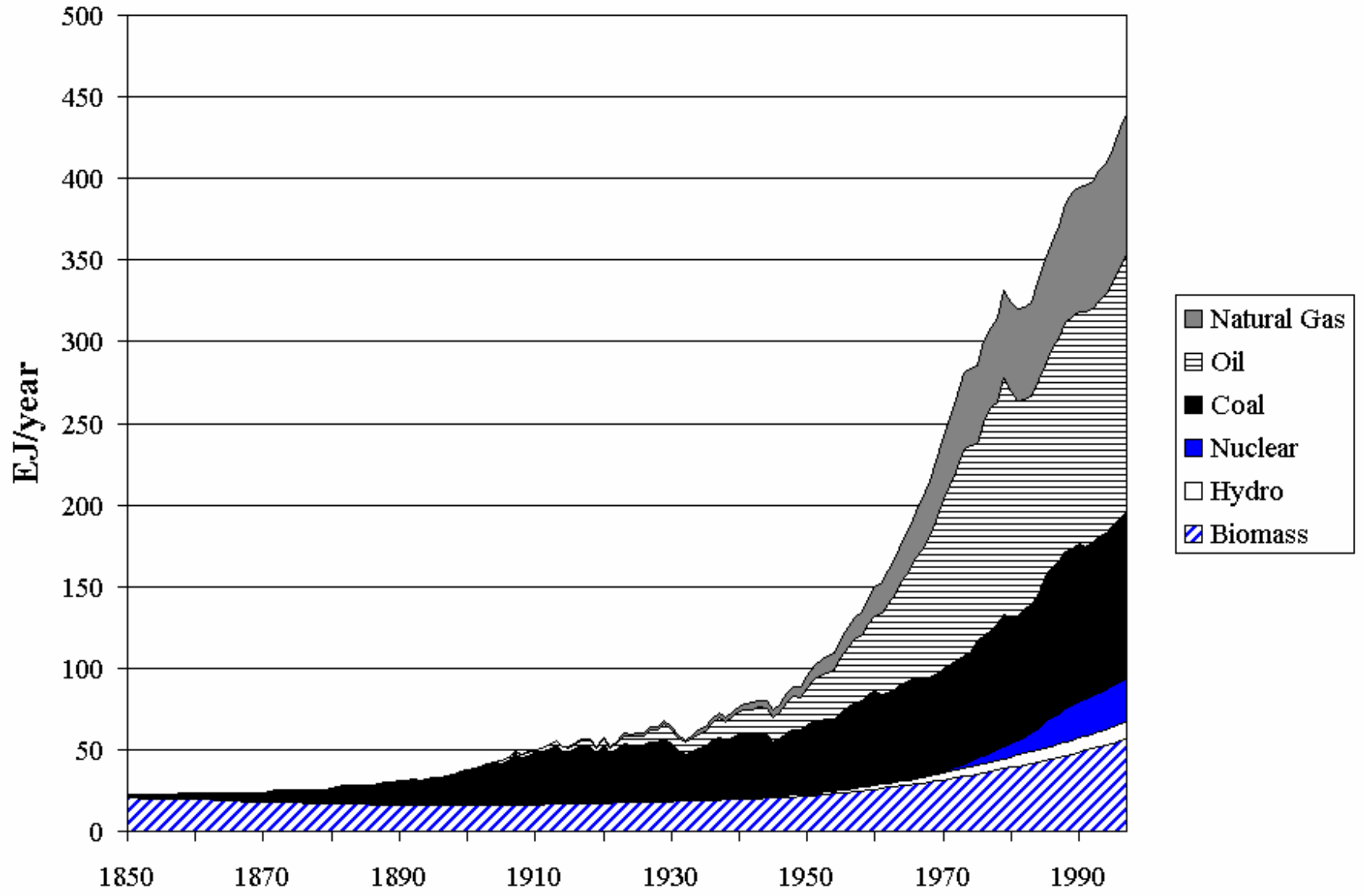
Sam Baldwin

Chief Technology Officer and Member, Board of Directors

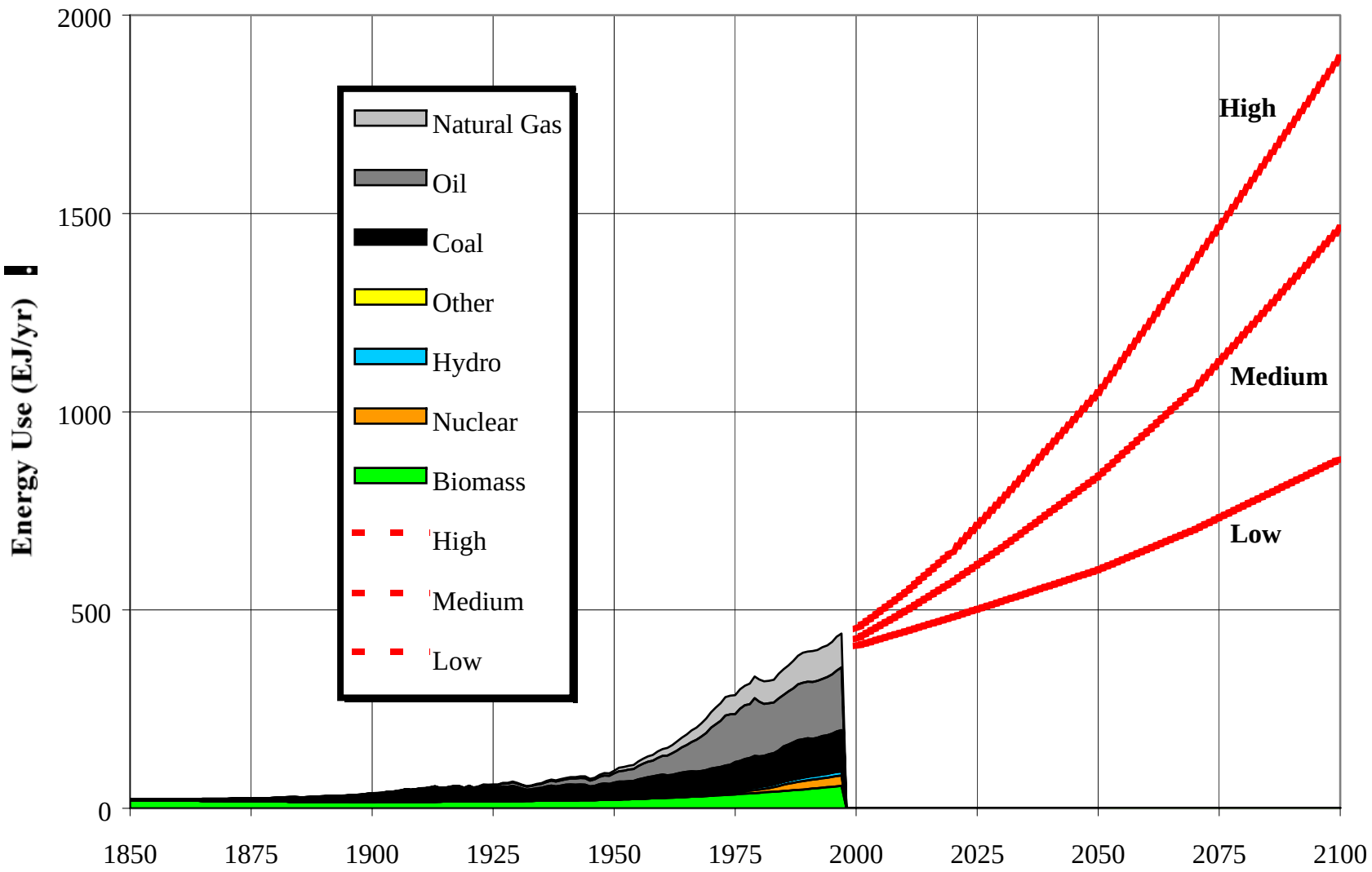
Office of Energy Efficiency and Renewable Energy

U.S. Department of Energy

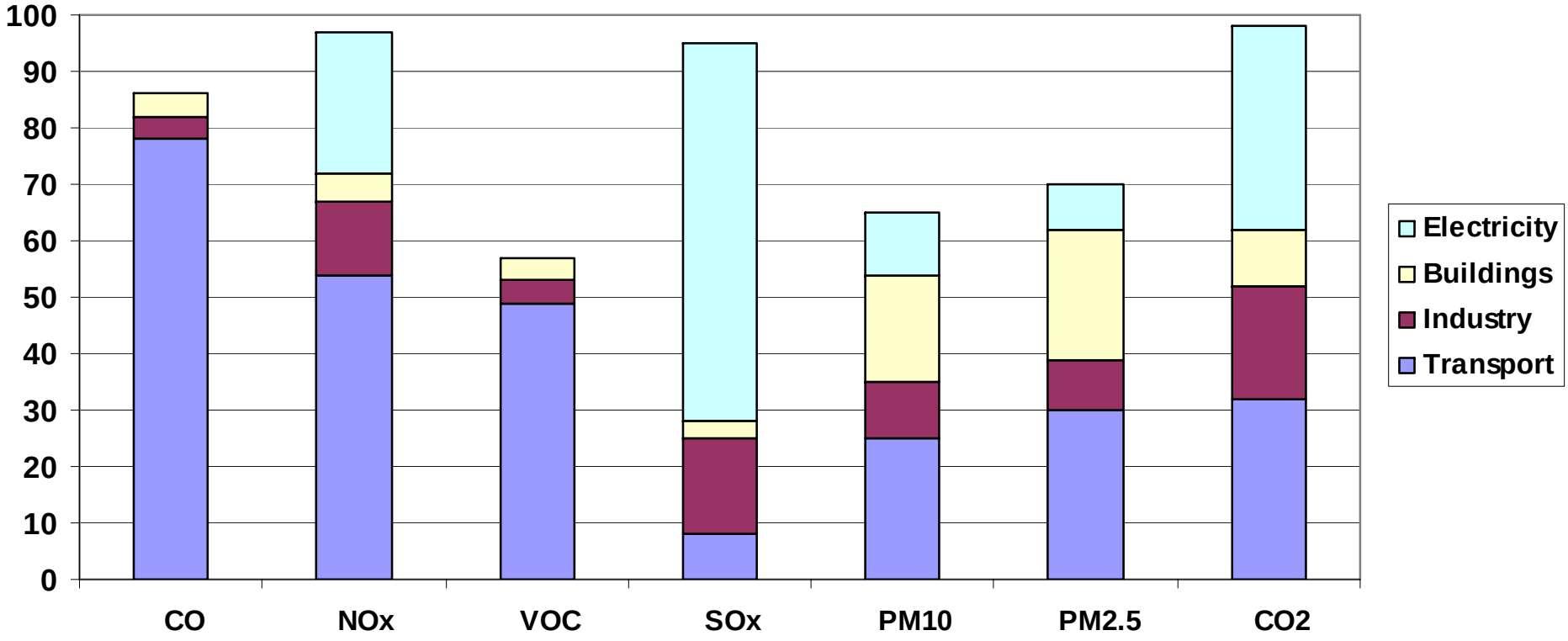
World Primary Energy Supply by Source, 1850-1997



Projections of Energy Use



U.S. 1998 Energy-Linked Emissions as Percentage of Total Emissions



What is EERE Doing?

EERE Vision, Mission, and Goals

Vision: A prosperous future where energy is clean, abundant, reliable, and affordable.

Mission: Strengthen America's energy security, environmental quality, and economic vitality through public-private partnerships that:

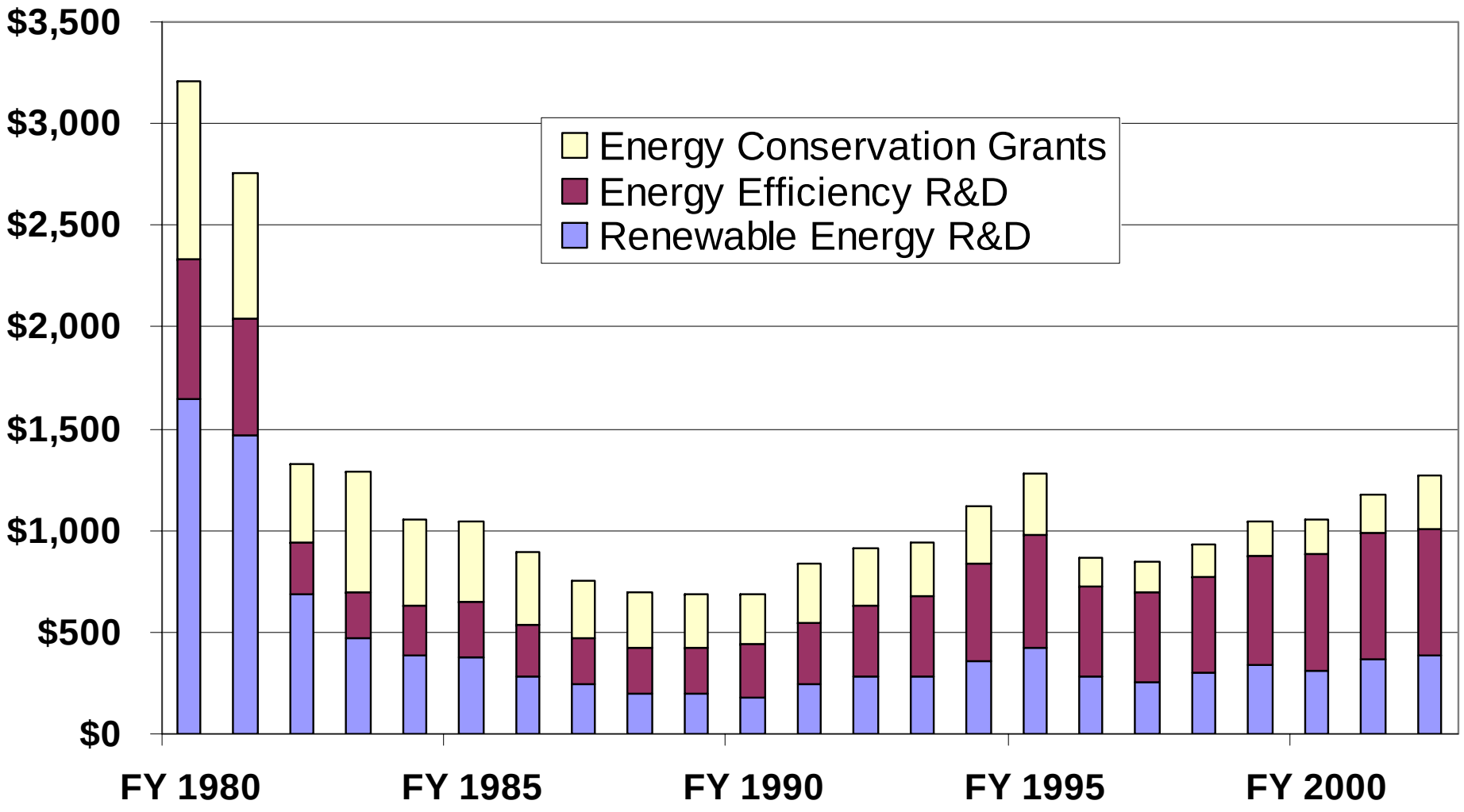
- Promote energy efficiency and productivity;
- Bring clean, reliable, and affordable energy technologies to the marketplace; &
- Make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life.

Goals:

1. End dependence on foreign oil.
2. Reduce burden of energy prices on disadvantaged.
3. Increase viability and deployment of renewable energy.
4. Increase reliability and efficiency of electricity generation.
5. Increase the efficiency of buildings and appliances.
6. Increase the efficiency/reduce the energy intensity of industry.
7. Create the new domestic bioindustry.
8. Lead by example through Government's own actions.
9. Change the way that EERE does business.

EERE Budgets 1980-2002

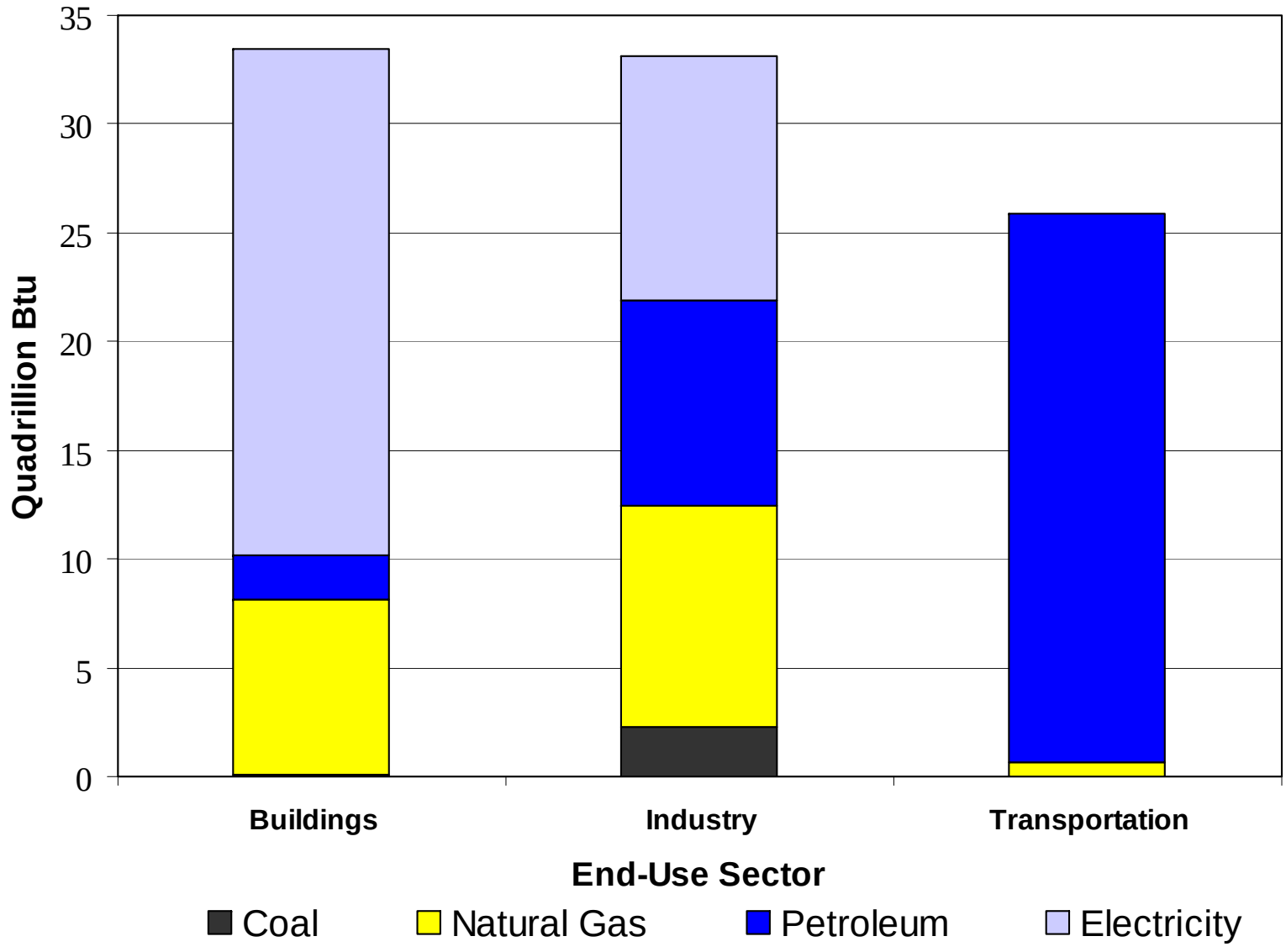
Millions of 2000$



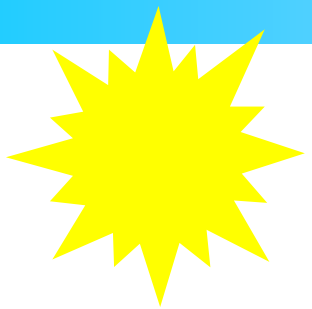
EERE Programs

- Solar
- Wind & Hydropower
- Geothermal
- Distributed Energy, Electricity Infrastructure and Reliability
- Biomass
- Industrial Technologies
- FreedomCAR & Vehicle Technologies
- Hydrogen, Fuel Cells & Infrastructure
- Building Technologies
- Weatherization & Intergovernmental Grants
- FEMP

Energy Consumption by End-Use Sector & Source

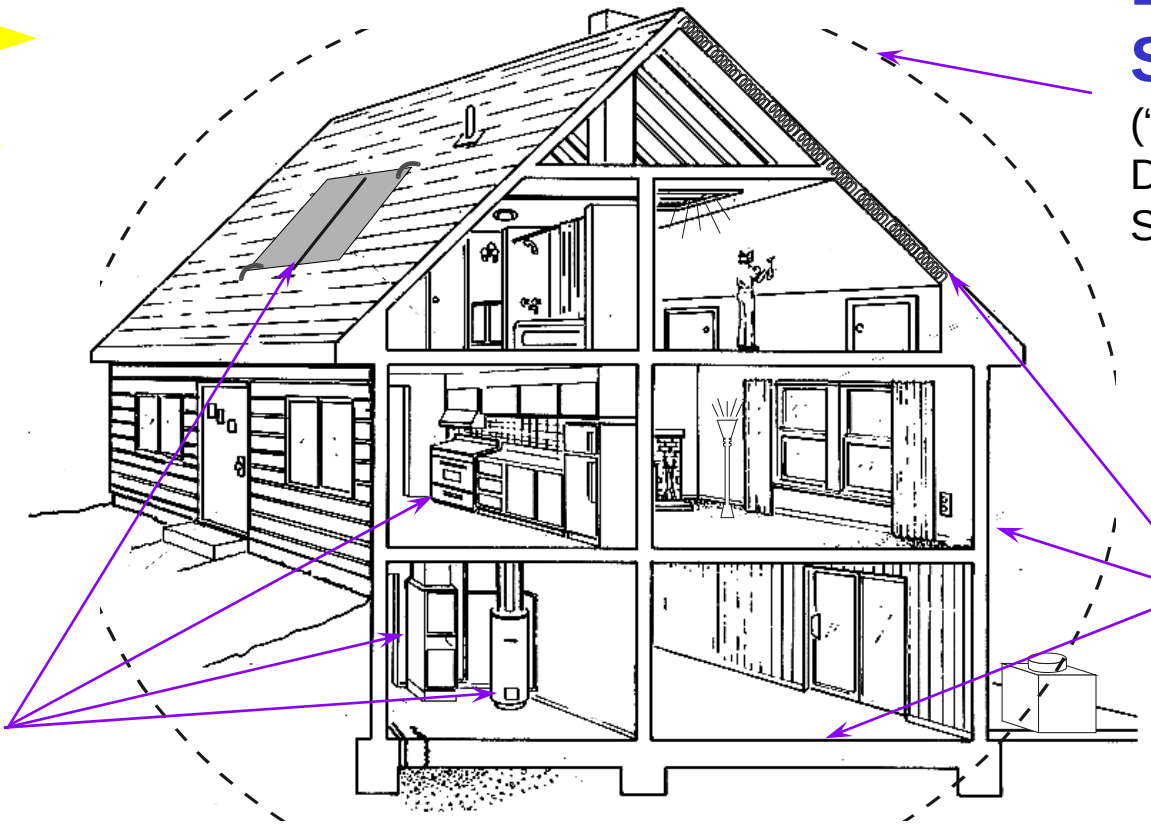


Buildings



Building Systems

("whole-systems")
Design tools
System Integration



Buildings consist of a complex system of interacting components facing variable input conditions

Building Envelope

Windows

Building Equipment

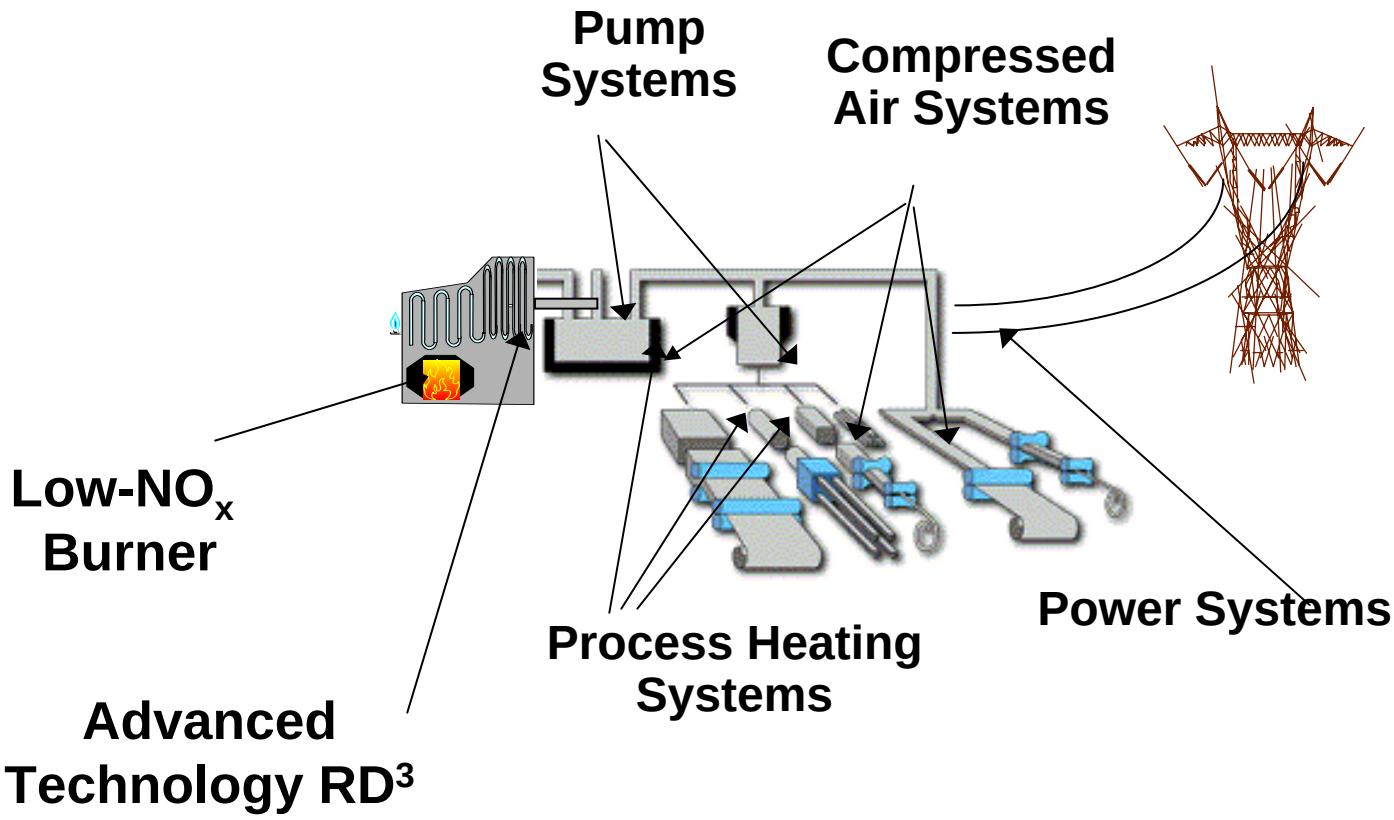
Space conditioning
Lights
Appliances
BIPV, PEM-FC

Materials Intensity

Science In the Buildings Sector

- **Advanced Refrigeration, Air Conditioning (FCVs):** (CFCs=>HFCs)
  - Magnetocaloric effect with Gd-Si-Ge alloys; Nd-Fe-B permanent magnets
- **Advanced Lighting**
  - LEDs, OLEDs, multiphoton phosphors (no Hg), nanostructured filaments
- **Windows**
  - Spectrally selective coatings, electrochromics
- **Power Electronics, Sensors, Controls**
  - Low-loss electronics
- **Water Heaters**
  - UV-, temperature-, and pressure-resistant polymers

Industry


Pump Systems
Compressed Air Systems
Low-NO_x Burner
Advanced Technology RD^3
Process Heating Systems
Power Systems

Science in the Industrial Sector

- **Advanced Materials; Advanced Processes**
  - **Longer lifetimes, substitutes; advanced processing techniques**
- **Efficient, high temperature separations**
  - **High temperature membranes, filters; Separation in multicomponent systems**
- **Improved process control**
  - **Sensors (high operating temperatures, sensitivities)**
- **Chemical, petroleum refining operations**
  - **Heterogeneous catalysis/surface chemistry; homogeneous catalysis/metalorganic chemistry; separation science; materials properties/synthesis; diagnostics**
- **Boilers, furnaces, gasifiers**
  - **Efficiency, emissions, gas cleanup: Combustion science; chemistry**
- **Industrial process flows, heat transfer, etc.**
  - **Multiphase flows, heat transfer, etc.: Computational fluid dynamics.**
- **Metal castings**
  - **Alloys: alloy chemistries, properties, processing: Materials Science**
  - **Rapid, non-destructive evaluation of alloy chemistry/properties: Diagnostics**

Transportation Technology

Hybrid Systems R&D

Heavy Vehicle Systems R&D

Advanced Combustion Engine R&D

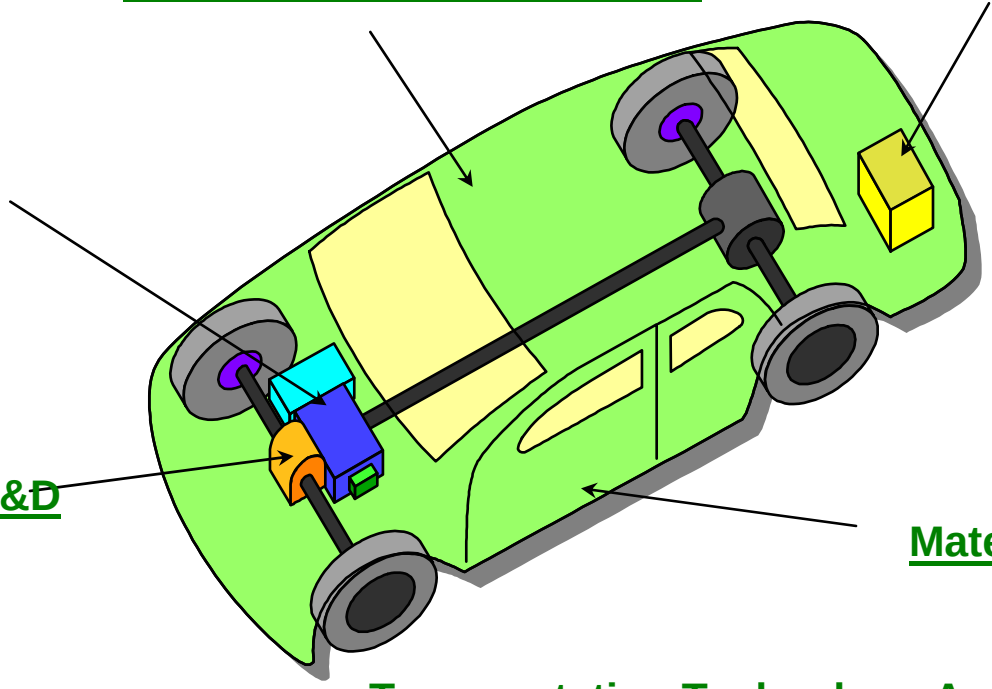
Fuel Cell R&D

Electric Vehicle R&D

Fuels Utilization R&D

Biofuels

Material Technologies

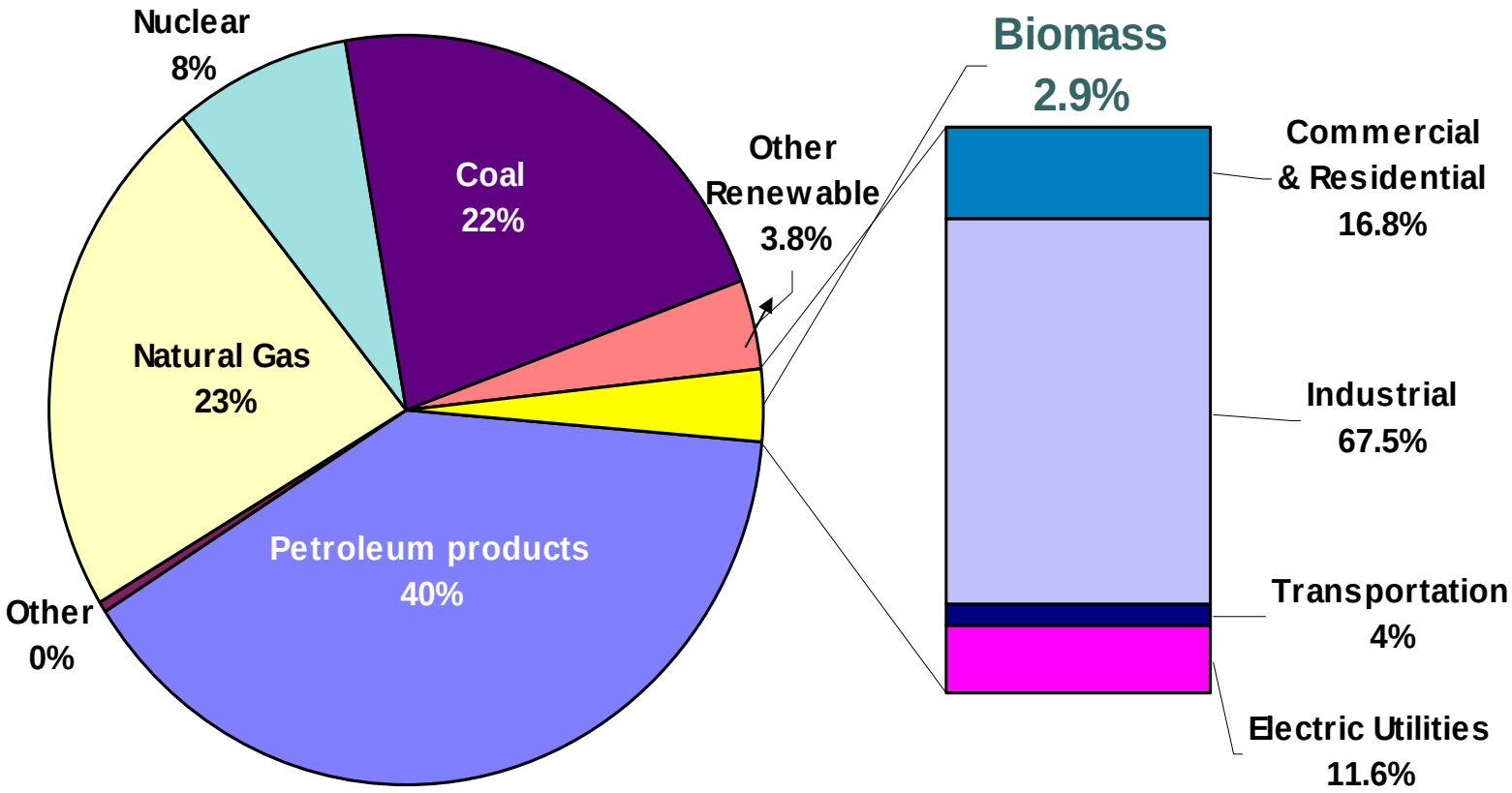


Transportation Technology Assistance

Science in the Transport Sector

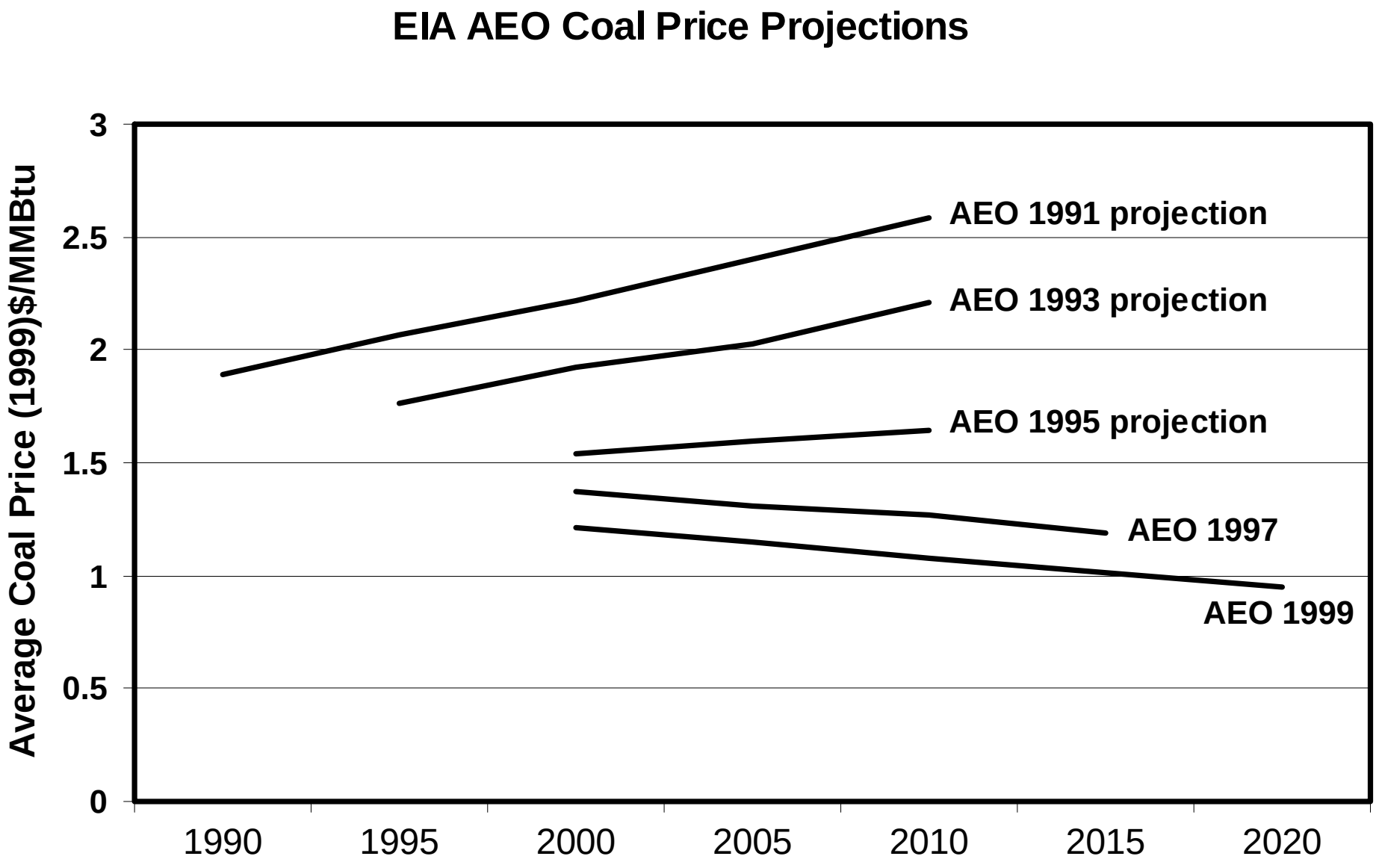
- **Advanced Fuels:** petroleum-based, biomass-based
- **High performance engines**
  - Real-time, high sensitivity multispecies measurements => Diagnostics.
  - Soot formation and evolution => Chemistry
  - Lean NOx catalysts w. high conversion rate over a wider exhaust temp range
  - Low speed flows; turbulence; multiphase flows => CFD
- **Hydrogen production and storage**
  - Fossil fuels; biomass; nuclear; solar; solar thermochemical (S-I, other cycles)
  - Carbon nanostructures, chemical hydrides.
- **Fuel Cells:** Cost, platinum loading, fuel processing/reformers, water/air mgmnt
  - Electrocatalysis, ionic transport in polymer electrolytes, fuel processing catalysis
- **Aerodynamic drag:**
  - Low speed flow; turbulence => CFD
- **Frames:**
  - Composite materials => Materials Science
- **High Power Energy Storage**:
  - Abuse Tolerance, Electrochemistry
- **Advanced Motors/Power Electronics**: Cost ($4/kW, $7/kW), Reliability (15y)

Bioenergy



Total Consumption = 96 Quads
Biomass = 2.9 Quads

Research Design



Biorefinery

Biomass Feedstock

– Trees
– Forest Residues
– Grasses
– Agricultural Crops
– Agricultural Residues
– Animal Wastes
– Municipal Solid Waste

Conversion Processes

- Acid Hydrolysis/Fermentation
- Enzymatic Fermentation
- Gas/liquid Fermentation
- Thermochemical Processes
- Gasification/Pyrolysis
- Combustion
- Co-firing

USES

Fuels:
Ethanol
Renewable Diesel
Methanol
Hydrogen

Electricity

Heat

Products
– Plastics
– Foams
– Solvents
– Coatings
– Chemical Intermediates
– Phenolics
– Adhesives
– Fatty acids
– Acetic Acid
– Carbon black
– Paints
– Dyes, Pigments, and Ink
– Detergents
– Etc.

Science in Bioenergy & Bioproducts

- **Feedstock production**
  - Plant growth and response to stress (and on marginal lands)**;**
  - Higher productivity at lower input (water, fertilizer, etc.)
  - Production of certain components and/or new components

  => Functional genomics; biochemistry; physiology; cellular control mechanisms; respiration; photosynthesis, metabolism, nutrient use, disease response
- **Biochemical pathways**

  => Biocatalysis: enzyme function and regulation; enzyme engineering; catalyst reaction rates and specificity
- **Thermochemical pathways**

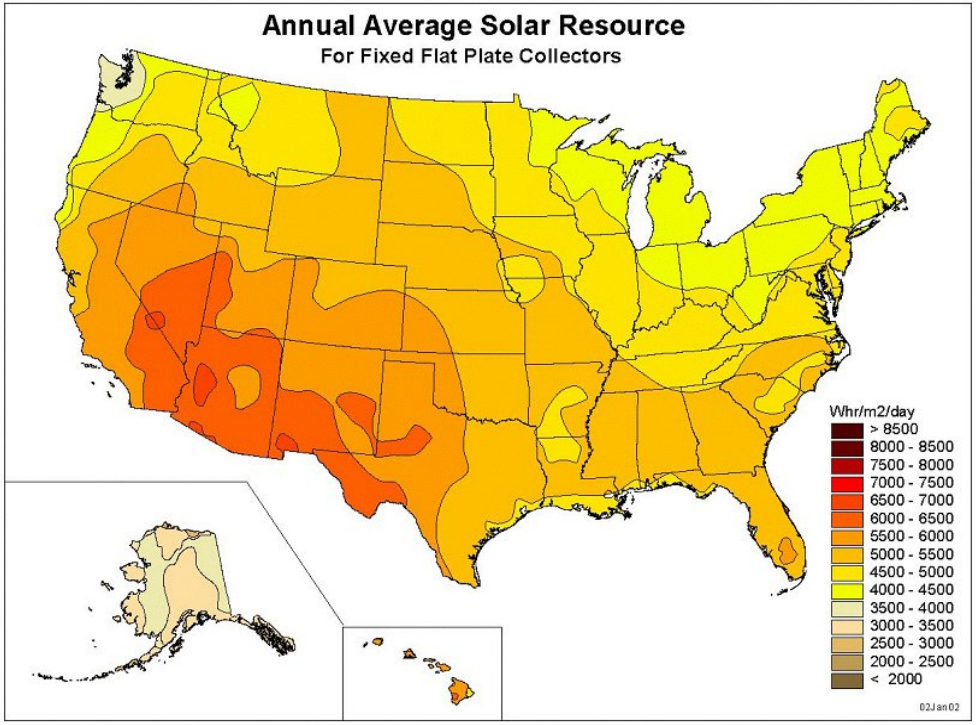
  => Product-selective thermal cracking of biomass; CFD modeling
- **Bioproducts**

  => New and novel monomers and polymers;
  - Biomass composites; => adhesion/surface science
- **Combustion**

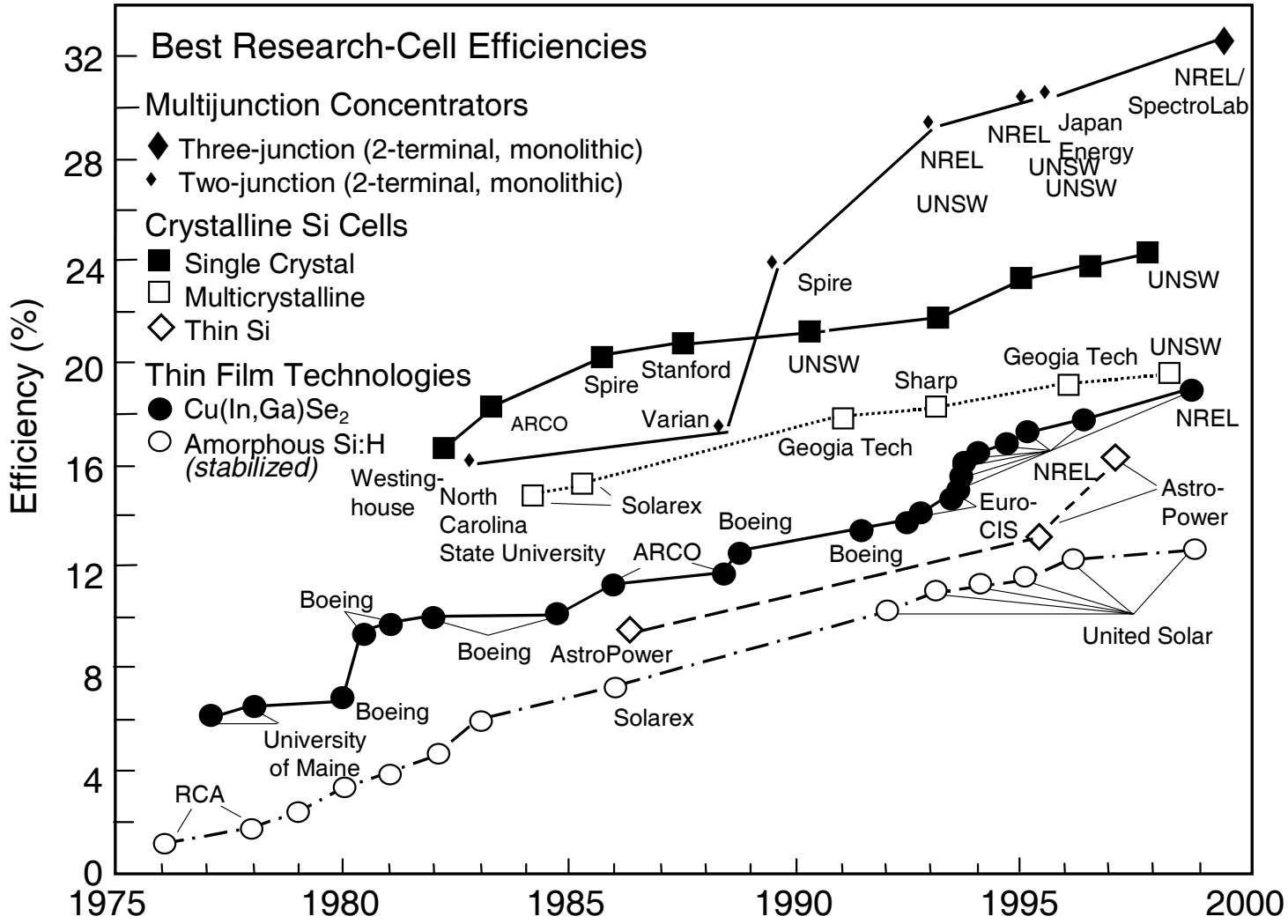
  => NOx chemistry; CFD modeling

U.S. Solar Resource (PV)

- **R&D has reduced of PV power from $2.00 per kilowatt-hour in 1980 to the current range of 20-38 cents per kilowatt-hour.**
- **2020 target: 5 cents per kilowatt-hour.**

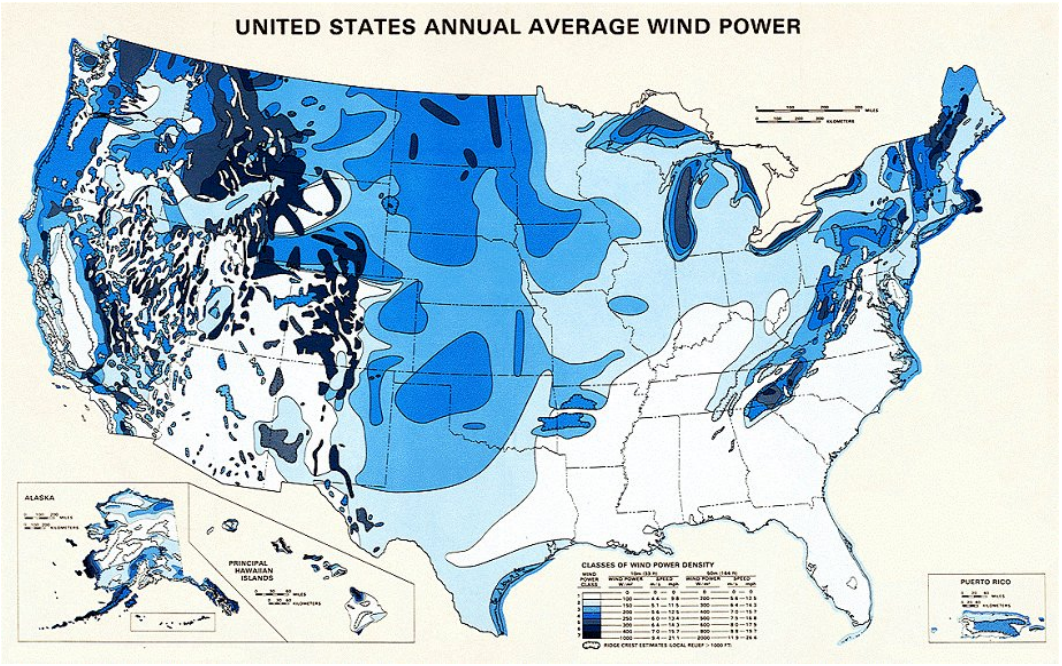


Best Research Cell Efficiencies



U.S. Wind Resource

- **R&D has reduced cost of wind power from 80 cents per kilowatt-hour in 1979 to a current range of 4-6 cents per kilowatt-hour (Class 6).**
- **2010 target: 3 cents per kilowatt hour (in Class 4 and above regimes.**
- **New R&D focus: low speed wind tech.; x20 resource; x5 proximity**



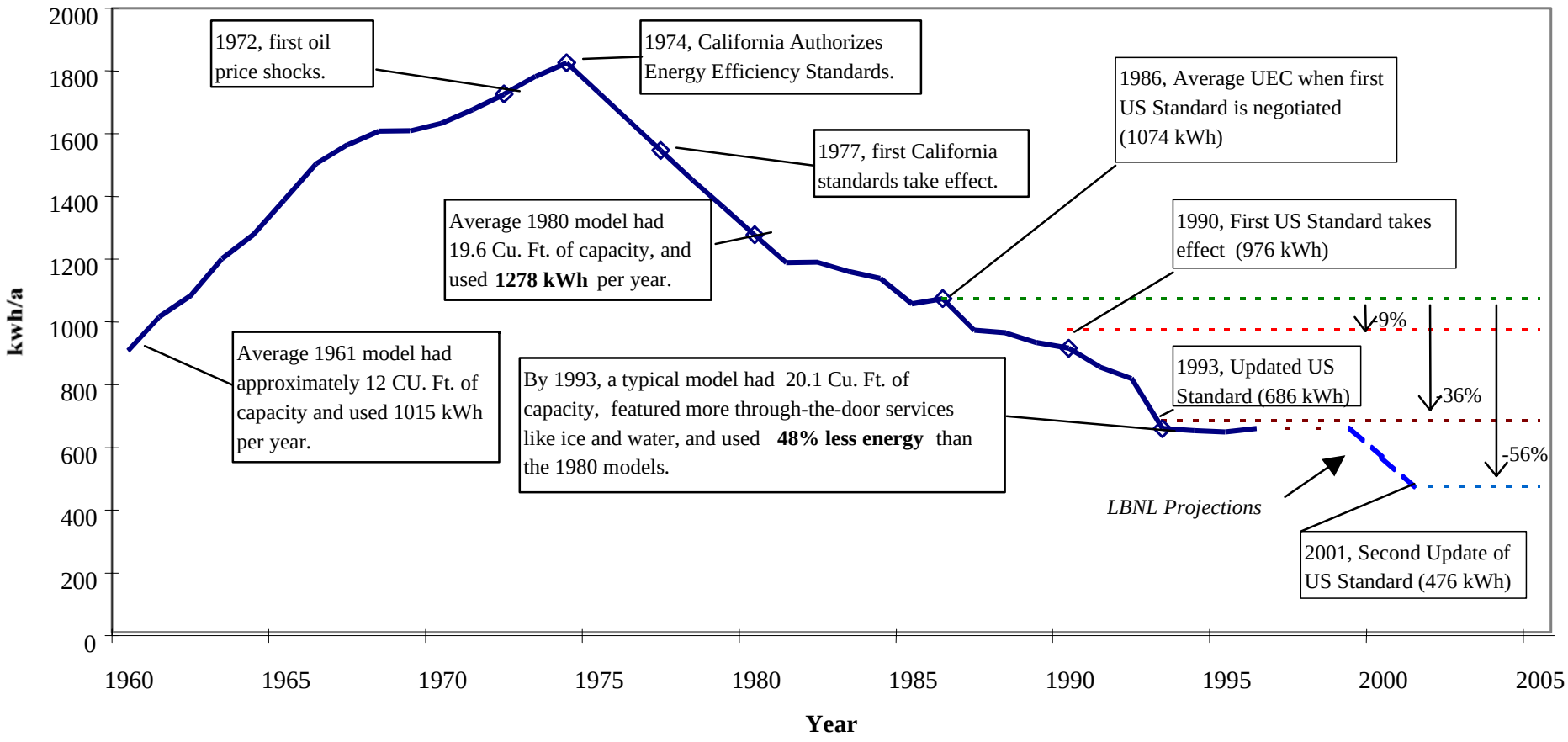
Science in the Power Sector

- **Photovoltaics**
  - Materials, growth, characterization,
  - multi-junction thin films—interface chemistry, physics, defects, materials compatibility; Quantum dot cells, multiple quantum well devices, etc.
- **Geothermal**
  - Geoscience: formation/flow of fluids through fractured media; characterizing geology; geochemistry; remote sensing
- **Wind**
  - Computational fluid dynamics to model turbulent flow for wind turbine design
  - Modeling meso-scale atmospheric phenomena for wind forecasting for utilities
  - Composite materials—materials strength, fatigue properties
- **Remote sensing**
  - algorithms for determining atmospheric and surface properties (aerosol optical depth, surface insolation, surface winds, bioenergy resources)

What has EERE accomplished?

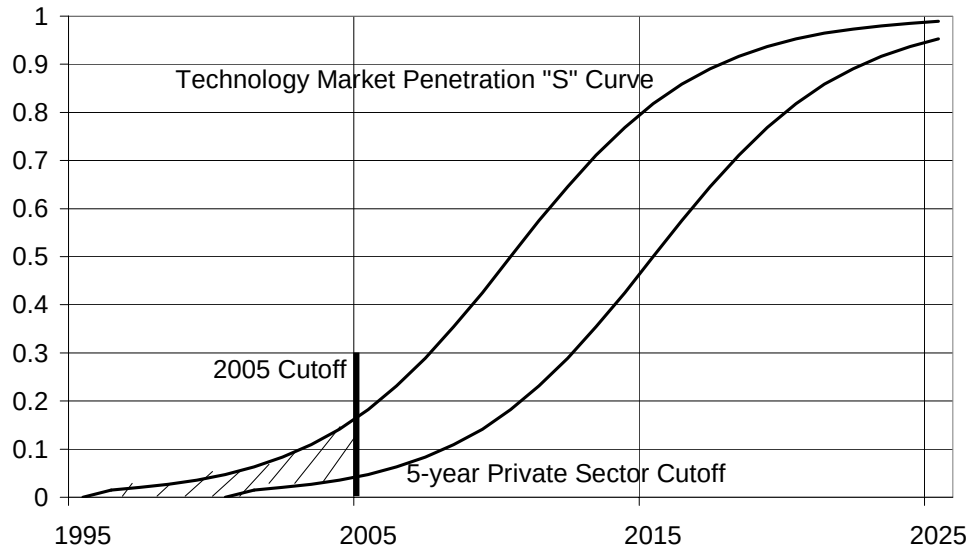
U.S. Refrigerator Energy Consumption

(Average energy consumption of new refrigerators sold in the U.S.)



NAS/NRC Study:
Energy Research at DOE: Was It Worth It?

	Realized Benefits and Costs	Options Benefits and Costs	Knowledge Benefits and Costs
Economic Benefits and Costs			
Environmental Benefits and Costs			
Security Benefits and Costs			



- **The NAS/NRC Framework assumes that the effect of public support of R&D accelerates development and penetration by 5 years. The NRC characterized their methodology as "very conservative"**
- **The review of $1.6 billion worth of EERE R&D activities (one-fifth of the total) over the past twenty years found $30 billion in realized net economic savings, and $3-20 billion in environmental benefits.**
- **The Strategic Program Review identified numerous additional technologies with likely large economic and environmental benefits.**

Where is EERE going?

Strategic Program Review of EERE

- **Historic Performance**
  - Patents, Awards, Technical accomplishments
- **Performance-based**
  - Technology push to market pull; components to integrated systems
  - Competitive solicitations; Goals, metrics, milestones; Peer review; Graduations and terminations
- **Public-Private Partnerships**
  - Partnering
  - Contracting
  - Cost-sharing
- **Costs and Benefits**
- **Business Performance**

SPR Recommendations

- **Closures:** activities that should be closed because the work has been successfully completed and no significant further government role is needed (graduations), or does not provide sufficient public benefits (terminations).
- **Redirections:** activities that potentially provide appropriate public benefits but need redirection and/or redefinition to increase the probability of success.
- **Watch List:** activities that need close monitoring to ensure that they advance effectively and expeditiously.
- **Expansions:** activities not currently receiving adequate support in comparison to the benefits they can provide.
- **Best Practices:** actions to improve overall program performance.

Criteria for Judgments

- **Projected Benefits** (economic, environmental, security, options) vs investment
- **Projected potential for commercialization** by industry**.**
- **Whether industry could or would do the RD3 by itself**
- **Program effectiveness (**technical performance, business management, etc.)

http://www.eren.doe.gov/pdfs/strategic_program_review.pd

Challenges in R&D Management

- **Diverse portfolios:**
  - Address national economic, environmental, security, infrastructure, etc. goals
  - Address multiple markets – buildings, industry, transport, electricity, fuels
  - EERE has 11 programs with about 3000 projects
- **Very long timeframes**
  - Up to 20+ year timeframes for R&D; followed by market penetration
- **Multiple performance criteria for the technology**
  - Multiple advances often needed: performance, cost, lifetime, size, density
- **Discontinuous changes in markets**
  - Hydrogen vehicles and infrastructure
- **Different measures needed for program results and portfolio benefits**
  - Technology performance versus emissions reductions, oil savings, etc.

R&D Management

- **Multi-Year Program Planning**
  - Modeling and Simulation; Off-Ramps; etc.
- **Research Integration**
  - Across programs; disciplines; basic to applied science; research to deployment
- **Benefits Analysis**
  - NAS Framework
  - Understanding how markets interact
- **Portfolio Analysis**
  - Computational Finance

Time Constants

- **Consensus building** — **~ 2-20+**
- **Science** — **~10+**
- **Technical R&D** — **~10+**
- **Production model** — **~ 4+**
- **Financial** — **~ 2+**
- **Market penetration** — **~10-20+**
- **Capital stock turnover** — **~15-100+**
  - Cars — 15
  - Appliances — 10-20
  - Industrial equipment/facilities — 10-30/40+
  - Power plants — 40
  - Buildings — 40-80
  - Urban form — 100's

- **Lifetime of Greenhouse Gases** — **~100's-1000's**